More examples of Buffer calculations

0.15 mol L^{-1} NH_3 and 0.50 mol L^{-1} NH_4Cl make up a buffer solution. What is the pH of the buffer solution? K_a NH_4^+ = 5.8 x 10^{-10}

$$NH_4^+(aq) + H_2O(l) \rightleftarrows NH_3(aq) + H_3O^+(aq)$$

Using K_a

$$K_a = \frac{[NH_3][H_3O^+]}{[NH_4^+]}$$

$$5.8 \times 10^{-10} = \frac{[0.15][H_3O^+]}{[0.50]}$$

$$\frac{(5.8 \times 10^{-10})(0.50)}{0.15} = [H_3O^+]$$

$$1.933 \times 10^{-9} = [H_3O^+]$$

$$pH = -\log 1.933 \times 10^{-9}$$

$$pH = 8.713$$

Answer: 8.71

OR

alternative method using H-H equation

$$pK_a = -\log K_a$$

$$pK_a = -\log (5.8 \times 10^{-10})$$

$$pK_a = 9.236$$

$$pH = 9.236 + \log \frac{0.15}{0.50}$$

$$pH = 9.236 + \log 0.3$$

$$pH = 9.236 + (-0.5228)$$

$$pH = 8.713$$

Answer: 8.71

5.78g of sodium ethanoate was added to 1 litre of 0.1 mol L^{-1} ethanoic acid. What is the pH of the buffer solution? K_a (CH_3COOH) = 1.8 x 10^{-5}
M(CH_3COONa) = 82 g mol^{-1}
Assume that the added mass of sodium ethanoate does not change the total volume of solution

$$CH_3COOH(aq) + H_2O(l) \rightleftarrows CH_3COO^-(aq) + H_3O^+(aq)$$

$$n = \frac{m}{M}$$

$$n\ (CH_3COONa) = \frac{5.78}{82}$$

$$n\ (CH_3COONa) = 0.07048 \text{ mol}$$

$$C\ (CH_3COONa) = \frac{n}{V}$$

$$C\ (CH_3COONa) = \frac{0.07048}{0.1} = 0.7048 \text{ mol } L^{-1}$$

Using K_a

$$K_a = \frac{[CH_3COO^-][H_3O^+]}{[CH_3COOH]}$$

$$1.8 \times 10^{-5} = \frac{0.7048\ [H_3O^+]}{0.1}$$

$$2.553 \times 10^{-6} = [H_3O^+]$$

$$pH = -\log 2.553 \times 10^{-6}$$

$$pH = 5.592$$

Answer: 5.59

OR

alternative method using H-H equation

$$pK_a = -\log K_a$$

$$pK_a = -\log (1.8 \times 10^{-5})$$

$$pK_a = 4.744$$

$$pH = 4.744 + \log \frac{0.7048}{0.1}$$

$$pH = 4.744 + \log 7.048$$

$$pH = 4.744 + 0.8480$$

$$pH = 5.592$$

Answer: 5.59

2.64g of $Na_2HPO_4.12H_2O$ and 0.31g of $NaH_2PO_4.2H_2O$ made up a buffer solution with a volume of 1 litre. What is the pH of the buffer solution? K_a $H_2PO_4^-$ = 6.3 x 10^{-8}
M ($Na_2HPO_4.12H_2O$) = 358 g mol^{-1}
M ($NaH_2PO_4.2H_2O$) = 156 g mol^{-1}

$$H_2PO_4^-(aq) + H_2O(l) \rightleftarrows HPO_4^{2-}(aq) + H_3O^+(aq)$$

$n = \frac{m}{M}$	
$n\ (Na_2HPO_4.12H_2O) = \frac{2.64}{358}$ $n\ (Na_2HPO_4.12H_2O) = 7.374 \times 10^{-3}$	$n\ (NaH_2PO_4.2H_2O) = \frac{0.31}{156}$ $n\ (NaH_2PO_4.2H_2O) = 1.987 \times 10^{-3}$
$C = \frac{n}{V}$	
$C\ (Na_2HPO_4.12H_2O) = \frac{7.374 \times 10^{-3}}{1}$ $C = 7.37 \times 10^{-3}$ mol L^{-1}	$C\ (NaH_2PO_4.2H_2O) = \frac{1.987 \times 10^{-3}}{1}$ $C = 1.99 \times 10^{-3}$ mol L^{-1}

Using K_a

$$K_a = \frac{[HPO_4^{2-}][H_3O^+]}{[H_2PO_4^-]}$$

$$6.3 \times 10^{-8} = \frac{7.37 \times 10^{-3}\ [H_3O^+]}{1.99 \times 10^{-3}}$$

$$1.703 \times 10^{-8} = [H_3O^+]$$

$$pH = -\log 1.703 \times 10^{-8}$$

$$pH = 7.768$$

Answer: 7.77

OR

alternative method using H-H equation

$$pK_a = -\log K_a$$

$$pK_a = -\log (6.3 \times 10^{-8})$$

$$pK_a = 7.2$$

$$pH = 7.2 + \log \frac{7.37 \times 10^{-3}}{1.99 \times 10^{-3}}$$

$$pH = 7.2 + \log 3.703$$

$$pH = 7.2 + 0.5686$$

$$pH = 7.768$$

Answer: 7.77

50mL of 0.15 mol L^{-1} Lactic acid (HLac) is mixed with 35mL of 0.25 mol L^{-1} Sodium lactate (Lac^-) what is the pH of the buffer solution?
Ka (HLac) = 1.38×10^{-4}

$$HLac(aq) + H_2O(l) \rightleftarrows Lac^-(aq) + H_3O^+(aq)$$

final concentration = $\frac{\text{original concentration} \times \text{original volume}}{\text{final volume}}$	
C (HLac) = $\frac{0.15 \times 0.05}{0.085}$ C (HLac) = 0.0882 mol L^{-1}	C (Lac^-) = $\frac{0.25 \times 0.035}{0.085}$ C (Lac^-) = 0.1029 mol L^{-1}

Using K_a

$$K_a = \frac{[Lac^-][H_3O^+]}{[HLac]}$$
$$1.38 \times 10^{-4} = \frac{0.1029\,[H_3O^+]}{0.0882}$$
$$1.182 \times 10^{-4} = [H_3O^+]$$
$$pH = -\log 1.182 \times 10^{-4}$$
$$pH = 3.926$$

Answer: 3.93

OR

alternative method using H-H equation

$$pK_a = -\log K_a$$
$$pK_a = -\log (1.38 \times 10^{-4})$$
$$pK_a = 3.86$$
$$pH = 3.86 + \log \frac{0.1029}{0.0882}$$
$$pH = 3.86 + \log 1.166$$
$$pH = 3.86 + (0.0669)$$
$$pH = 3.926$$

Answer: 3.93

Calculate the ratio of carbonic acid concentration to bicarbonate ion concentration buffer in the blood which maintains a pH of 7.4.
K_a (H_2CO_3) = 4.3×10^{-7}

$$H_2CO_3(aq) + H_2O(l) \rightleftarrows HCO_3^-(aq) + H_3O^+(aq)$$
$$pH = -\log [H_3O^+]$$
$$\text{inverse log} - 7.4 = [H_3O^+]$$
$$3.98 \times 10^{-8} = [H_3O^+]$$

Using K_a

$$K_a = \frac{[HCO_3^-][3.98 \times 10^{-8}]}{[H_2CO_3]}$$
$$4.3 \times 10^{-7} = \frac{[HCO_3^-][3.98 \times 10^{-8}]}{[H_2CO_3]}$$
$$\frac{4.3 \times 10^{-7}}{3.98 \times 10^{-8}} = \frac{[HCO_3^-]}{[H_2CO_3]}$$
$$10.8 = \frac{[HCO_3^-]}{[H_2CO_3]}$$

Answer: $[HCO_3^-] : [H_2CO_3] = 11 : 1$

OR

alternative method using H-H equation

$$pK_a = -\log K_a$$
$$pK_a = -\log 4.3 \times 10^{-7}$$
$$pK_a = 6.366$$
$$7.4 = 6.366 + \log \frac{[HCO_3^-]}{[H_2CO_3]}$$
$$7.4 - 6.366 = \log \frac{[HCO_3^-]}{[H_2CO_3]}$$
$$\text{inverse log } 1.033 = \frac{[HCO_3^-]}{[H_2CO_3]}$$
$$10.78 = \frac{[HCO_3^-]}{[H_2CO_3]}$$
$$[HCO_3^-] : [H_2CO_3] = 11 : 1$$

Answer: $[HCO_3^-] : [H_2CO_3] = 11 : 1$

Calculate the concentration of $C_3H_5O_2^-$ in a buffer solution which has a pH of 4.5 if the concentration of $HC_3H_5O_2$ is 0.50 mol L^{-1}
K_a ($HC_3H_5O_2$) = 1.34×10^{-5}

$$HC_3H_5O_2(aq) + H_2O(l) \rightleftarrows C_3H_5O_2^-(aq) + H_3O^+(aq)$$
$$pH = -\log [H_3O^+]$$
$$\text{inverse log} - 4.5 = [H_3O^+]$$
$$3.16 \times 10^{-5} = [H_3O^+]$$

Using K_a

$$K_a = \frac{[C_3H_5O_2^-][H_3O^+]}{[HC_3H_5O_2]}$$
$$1.34 \times 10^{-5} = \frac{[C_3H_5O_2^-]\ 3.16 \times 10^{-5}}{0.50}$$
$$\frac{(1.34 \times 10^{-5})(0.50)}{3.16 \times 10^{-5}} = [C_3H_5O_2^-]$$
$$0.2120 = [C_3H_5O_2^-]$$

Answer 0.212 mol L^{-1}

OR

alternative method using H-H equation

$$pK_a = -\log K_a$$
$$pK_a = -\log (1.34 \times 10^{-5})$$
$$pK_a = 4.872$$
$$4.5 = 4.872 + \log \frac{[C_3H_5O_2^-]}{0.50}$$
$$4.5 - 4.872 = \log \frac{[C_3H_5O_2^-]}{0.50}$$
$$-0.372 = \log \frac{[C_3H_5O_2^-]}{0.5}$$
$$\text{inverse log } (-0.372) = \frac{[C_3H_5O_2^-]}{0.5}$$
$$(0.4246)(0.5) = [C_3H_5O_2^-]$$
$$0.2120 = [C_3H_5O_2^-]$$

Answer 0.212 mol L^{-1}